# CONSTRUCTIONAL MATERIALS

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## USE ASH-AND-SLAG MATERIALS OF HEAT POWER ENGINEERING IN THE CONSTRUCTION MATERIALS

**Abstract**. The possible trends to improve the building-technical properties of dry ashes characteristics formed as a result of solid fuel combustion at thermal power stations are presented. The resuets of different fly-ash conditioning technologies application to widen the trends and to increase the volumes of their use in the construction materials and products.

**Keywords**: fly-ash, properties, conditioning, grinding, classification, granulation, construction materials.

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## ИСПОЛЬЗОВАНИЕ ЗОЛОШЛАКОВЫХ МАТЕРИАЛОВ ТЕПЛОЭНЕРГЕТИКИ В СТРОИТЕЛЬНЫХ МАТЕРИАЛАХ

**Аннотация.** Представлены возможные направления улучшения строительно-технических характеристик сухих зол, образующихся при сжигании твердого топлива на тепловых электростанциях. Приведены результаты применения различных технологий кондиционирования свойств золы для расширения направлений и увеличения объемов их использования при производстве строительных материалов и изделий.

**Ключевые слова**: зола уноса, свойства, кондиционирование, измельчение, классификация, грануляция, строительные материалы.



### Introdaction

Ash-and-slag materials differ according to their chemical and mineralogical composition, dispersibility, chemical activity and fusion temperature due to the wide variety of solid fuel, different conditions of its combustion as well as different ways of its trapping and removing. In accordance with DR 34.09.603–88 chemical composition of ash-and-slag is subdivided into acid and main; fuel content — subdivided into ash-and-slag with low, middle and high content of fuel, accordingly, loss of ignition not more than 5, from 5 to 10 and more than 10 % accordingly; according to its dispersibility — subdivided into low dispersive, middle dispersive and high dispersive ash-and-slag with specific surface less than 150, from 150 to 300 and more than 300 $m^2/kg$ accordingly; according to the melting temperature — subdivided into low-melt, middle-melting and high-melting with fusion temperature 1250, from 1250 to 1450 and more than 1450 °C accordingly [1].

The main criteria for estimation of possibility to use ash-and-slag materials in building and construction material production are chemical composition, content of combustibles and free calcium oxide, specific surface, melting temperature. Additional characteristics of ash and slag are humidity, grain structure, bulk density, and the maintenance glassy particles of fly ash. First of all suitableness of ash and slag as the main raw material for production of construction materials is determined by lack or limited content of harmful components which deteriorate physical-mechanical properties of construction material and concretes and reduce their performance properties or hamper technological production processes and limit of application range.

Fly-ash, slag and ash-slag mixture obtained by burning solid fuel can be only used, if their properties meet the technical standard requirements. So, only certified fly-ash meetiny requirements of the GOST 25818–91 standart can be used in concretes. Fly-ash which doesn't meet this or that standard can be used for other purposes if it meets the necessary requirements or can be stored in dumps. From the information indicated above it should be pointed out that the ashes and slags quality which are recycled is strictly regulated. As far as the combustion fuel regimes at thermal power station (TPS) are concerned they do not always result in the obtaining of ash slags which are characterized by "standard set" of characteristics and properties. Due to such reason fly-ash or slag conditioning should be considered as ordinary operation in the technology of their utilization.

At present conditioning of fly-ash slag material as to a number of proper indications e. g. removal of hydrogen excess or dispersity increasing is not regulated. At the same time in the European EN 450–2005 "Fly ash for concrete" standard the requirements to the composition and properties of the conditioned fly-ash are established.

In a number of European countries there exist technologies for fly-ash conditioning, removal of hydrogen excess, grinding, activation and other operations. So, in Germany by means of air classification super-fine mineral fractions not more than 10–20 micro-meters are extracted which are introduced into concrete, peastics and paints. To meet season demand in dry fly-ash the installations for drying dumped fly-ash slag mixtures are used in Germany and France. In Great Britain the technologies allowing microspheres from fly-ash to be extracted which are used in concretes or as paints, plastics and paper fillers, but residual hydrogen is used as the replacement of coal or gas. Coarse and medium-size fractions of fly-ash are used in the const-ruction materials production. Possible directions of improvement of building-technical properties of thermal power station ashes are low presented.

## 1. Grinding

Fly-ash dispersity influences not only the fly-ash Portland cement properties, but working characteristics of its bases. L. Ya. Goldshtein's investigations have shown that replacement of 30 % cement (specific surface 320 m²/kg) with acid fly-ash which is fineground, the flowability of mortar mixture is decreasing but cement strength is increasing (see Table 1) [2]. Cement with fly-ash adition ground to specific surface 1050 m²/kg has compressive strength approximately equal to proper index for cement without any adition after 28 days of hardening. In the later period of hardening cements with fly-ash adition having high dispersity acquire strength of neat cement not more than 20 %. To evaluate the effectiveness of fly-ash pregrinding objectively one should calculate the additional energy expenses with the technological effect obtained.

Replacing traditional mineral raw materials with fly-ash initial dispersity of ash particles allows to decrease expenses for raw materials grinding especially at the stage of first recycling. However, the technological processes of such a kind are traditionally designed inicially to accept and recycle of natural lump raw material. As a result of the circumstance indicated the result is that replacement of "a lump" by "dust" in the working productions causes the definite difficulties which are connected not only with the adaptation of the equipment to dust raw material, but with the necessity of the fulfillment of certain dedusting operations of the technological processes proper.

## 2. Air classification

For the purpose of studying of influence of various ash fractions on cement stone durability fly-ash which have been selected from installation of shipment at the Reftinsky state district power station, have subjected to fractionating on multiserial centrifugal qualifier. Four cindery fractions (conditionally divided on the boundary size of particles 10 and 60 microns), differed with quantity and grain-size structure are received. The fine-dispersion fraction has been presented by particles with size less than 10 microns in number not less than 90 %. Ash particles with a size more than 60 microns has the greatest density, particles less than 10 microns — the least density.

Besides, fine-dispersion ash fraction has a high number of underburning (to 6 %), and in cindery fraction 10–60 microns it is absent. It is established that original ashes and its fractions increase water requirement of ash-portland cement and reduce density and durability of water hardening cement stone, especially considerably at its introduction in the quantity of 30 % of cement weight. However, after steaming at the age of 1 days the cement stone with the additive of original ash and its fractions less than 10 and more 10 microns has higher comparison durability than cement without ashes (Table 2).

Table 1

**Influence of fly-ash dispersity and the duration of hardening on the Portland cement strength**

| Portland Cement | Specific surface of fly-ash, m²/kg | Changing of strength on compression, %, in a day | | | |
|---|---|---|---|---|---|
| | | 7 | 28 | 90 | 180 |
| Without fly-ash | – | 64 | 100 | 114 | 134 |
| With 30 % fly-ash adition | 240<br>650<br>1050 | 46<br>51<br>56 | 77<br>89<br>98 | 112<br>133<br>133 | 124<br>144<br>147 |

Table 2

**Influence of ash fractions on physicomechanical properties of a cement stone**

| Ashes test | Quantity of ashes, mass. % | W/C | Density of a cement stone, kg/m$^3$ | Strength at compression, MPa, through, days | | | |
|---|---|---|---|---|---|---|---|
| | | | | Normal hardening | | After steaming | |
| | | | | 3 | 28 | 1 | 28 |
| Portland cement | 0 | 0,27 | 2320 | 42,3 | 61,6 | 39,7 | 67,7 |
| Initial ash | 15<br>30 | 0,34<br>0,46 | 2160<br>1990 | 37,7<br>20,9 | 52,3<br>34,4 | 44,9<br>36,1 | 71,1<br>49,4 |
| Fraction > 60 microns | 15<br>30 | 0,29<br>0,36 | 2270<br>2040 | 36,1<br>33,3 | 45,7<br>44,8 | 39,8<br>29,5 | 55,0<br>41,5 |
| Fraction 10–60 microns | 15<br>30 | 0,31<br>0,44 | 1850<br>1730 | 27,8<br>22,1 | 40,2<br>26,6 | –<br>– | –<br>– |
| Fraction < 10 microns | 15<br>30 | 0,37<br>0,47 | 2280<br>2130 | 27,9<br>24,4 | 42,9<br>34,9 | 44,1<br>36,1 | 60,0<br>57,3 |
| Fraction > 10 microns | 15<br>30 | 0,33<br>0,47 | 2150<br>1970 | 30,8<br>20,1 | 46,1<br>32,0 | 41,3<br>30,1 | 60,4<br>54,9 |

### 3. Combustible content decrease

The essential factor, limiting application of fly-ashes in building, presence in their structure of residual carbon which, as a rule, is estimated by weight losses at calcining. Negative influence of coke rest as a part of ashes is shown in durability decrease of a cement-ash stone by absorption by carbon hydroxide of calcium formed at cement minerals hydration that breaks optimum in hydration products balance of the mentioned minerals.

Most strongly this factor is shown by consideration of questions of ashes processing of Kuznetsk, Donetsk, Vorkuta and other coals with a small fly-ash exit at traditional torch burning of them. For ashes of the specified coals the loss of ignition fluctuate in range from 10 to 25 %, and sometimes can reach 35–40 %. It is possible to assert that on majority thermal power station there are certain technical possibilities for reducetion of fuel losses with mechanical underburning. It is established carbon in ashes, as a rule, is presented large, the size about 0,5–1 mm, fractions. From the specified follows that crushing process of fuel not on all thermal power stations has been optimized. The integrated fraction of boiler fuel demands a bigger time for full combustion, rather than duration of their stay in fire chamber space. We believe that installation of separators on coal mills regulating particles size, arriving on burning, will allow to avoid surplus coke rest in ash. Alternative to this variant is creation of technological lines on division of ashes into compo-nents with the differentiated maintenance of carbon. Earlier we offer a similar variant of such line at the boiler unit [3]. In world practice wide enough industrial application was received by technology of Company Separation Technologies [4].

### 4. Granulation

Granulation is one of effective ways of improvement of consumer properties ash-slags materials [5]. More often it use in technologies of reception of easy fillers for concrete [6]. Granulation allows to simplify essentially application of fly ashes as a substitute of natural raw materials. It allows to exclude application of expensive special technics for their shipment, transportation and preparation to traditional "know-how" of a various commodity output. It is rather important that the granulated ashes, in essence, combine advantages of lump materials and initial ashes as the cindery granules made without burning of technologies, are usually easily crushed at a joint grinding with other components.

Granulation for high calcium ashes from burning of brown coals of Kansko-Achinsk pool is especially effective. It is established that such ashes are well granulated, an exit of granules in the size less than 5 mm 5 %, a share of fraction do not exceed of 10–20 mm was in limits of 77–85 %, and their dot durability made durability to 30 N/granule. The greatest strength had granules made of fly-ash received by burning coal in the boilers with firm slag removal (Table 3). To store the granulated ashes in a sailing not only provides to save its building-technical properties, but also, simultaneously, excludes toxic influence of ashes on an environment (Table 4) .

Noted advantages of a granulated ash do not expel piling possibility high calcium ashes of dry selection in the moistened condition, however consumer properties at stabbed is malicious worse, than at the grained. Thus the comparative estimation of their properties for the purpose of the subsequent use should be defined, in our opinion, consideration of set of following criteria:

Table 3

**Properties of cindery granules in depandance from a way of burning of brown coal**

| Indicators | Method of fuel burning | | |
|---|---|---|---|
| | Liquid slag removal | Solid slag removal | Circulating boiling layer |
| Water requirement of ashes, % | 18–28 | 30–36 | 40–70 |
| Bulk density, kg/m$^3$ | 900–1200 | 800–1100 | 700–1000 |
| Average density, kg/m$^3$ | 1560–1970 | 1090–1460 | 1080–1320 |
| Quantity launches granules from height of 0,3 m | 5–15 | 4–6 | 3–15 |
| The maximum height launch, m | 0,8–1,5 | 1,0–1,5 | 0,5–1,0 |
| Durability at compression in 1 days harden, N/granule | 0–100 | 60–120 | 5–50 |

Table 4

**Change of properties of cindery granules at atmospheric storage within 4 months**

| The characteristic name, dimensions of a quantity | Magnitude | | Change, % |
|---|---|---|---|
| | Initial | After storage | |
| Average density, kg/m$^3$ | 1350 | 1655 | +22,6 |
| Bulk density, kg/m$^3$ | 850 | 998 | +17,4 |
| Water absorption, % | 28 | 11 | –60,6 |
| Compressive strength in the cylinder, MPa | 1,43 | 3,36 | +134,9 |
| Weight loss at calcination, % | 17,3 | 24,5 | +41,6 |

• conformity to demands of ecological certificates;

• ash-slag stable phase and chemical compositions, humidity, stability against caking and freezing, and also absence of dusting;

• the maintenance of useful components in an optimum aspect, for example, calcium oxides in an aspect to exhaust or clinker minerals;

• convenience agregation to conditions for the subsequent reference;

• an invariance of ash slags properties at transportation;

• susceptibility of a demand level for ash slags to seasonal fluctuations and another.

## Conclusion

The ways of increasing building-technical properties of ash-and-slag materials of thermal power stations are considered. The effectiveness of ash-and-slag materials application depends both on composition and properties and the trends of ash-and-slag processing into construction materials and products.

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